Site Facilities

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X.1. GENERAL SUMMARY - FACILITIES

X.1.1. Introduction

This report presents the site facilities cost estimate, preliminary layout, and site location map for the CHARA Array. Excluded are costs associated with the optical telescopes and their site pad developments, light beam transmission systems, optical equipment, and related systems. The costs are site specific. A brief discussion is included regarding costs and estimates for providing access and on-site utilities at the CHARA site.

X.1.2. Status

The estimate is based upon the preliminary Array layout as provided by CHARA and modified for the site and its location relative to the acquistition of local construction materials and contractors. The Preliminary Geotechnical Investigation, completed by SHB Agria, Inc. (see Appendix W) has been reviewed relative to site soils and foundations. Site topography has been provided by Koogle & Pouls Engineering. Meetings and phone discussions were held to discuss the facilities in general and the estimated requirements. The site is located in central New Mexico on the Acoma Indian Reservation approximately 80 miles west of Albuquerque and 17 miles south of Grants. Currently the site is not accessible to vehicle travel. No definitive construction date is known for either site access or facilities proper.

X.1.3. Assumptions & Costs to Access Site

The cost estimate assumes that various site specific systems will be provided to CHARA at the site and that various building systems can be functionally modified to fit the intended use. These include the following:

1. Natural gas is not anticipated at the site.

2. The site is accessed via NM Route 117 which is a two-lane paved highway from I-40 south through the El Malpais National Conservation Area. At the La Ventana Ranch, approximately 6 miles south of I-40, a dirt surfaced road runs south for approximately 3 miles in the valley along the westside bluff of Mesa Negra. Beyond this point an approximately 4 mile mountain road could be built up the southwest and south face of the bluff to the mesa top. The road is principally on Government and Indian land. For construction purposes the new access road should nominally be two lanes (20-ft width) with shoulders such that a 30-ft wide load could be transported along it and power constructed within the right-of-way. Access road surfacing is assumed gravel or base course. Excluding right-of-way costs, the new road could likely be constructed for about $500,000 per mile. Improvement of an existing roadway would run about $150,000 per mile.

3. The nearest power/telephone source is in the vicinity of the La Ventana Ranch and/or El Malpais Ranger Station along NM Route 117. It is supplied by Continental Divide Power. The power available is 14.4 kv single phase. Three-phase 14.4/24.9 kv, four wire, delta is avaliable at Interstate 40 seven miles north of the Ranger Station. The site is likely to be accessed by a road from the south side of the mesa as noted above, hence power likely will be located in the road right-of-way. Power requirements for economical pumping of water and required site facilities is three-phase, hence power will likely be run from I-40 to the site and, as necessary, to water sources. Estimated cost to provide three phase power is \$40,000 – \$45,000 per mile overhead along a roadway. Single-phase power is estimated at \$30,000 – \$35,000 per mile. If road right-of-way is not utilized and the line is in rough terrain, the costs nearly double. Non-mountainous terrain is about 10% less. If the pole system from I-40 to La Ventana is capable of use for three-phase power, the only cost associated with that segement of power would be wire and minor pole configuration changes. This would likely be on the order of \$10,000 per mile.
4. The water source is a well or spring. The nearest source is the Mesa Negra Spring which is approximately 2 air/ground miles northeast of the site at elevation 7682 ft on Acoma land. Another source is on the La Ventana Ranch, approximately 4.5 air miles (7 ground miles) to the northwest at elevation 6630. The site is at elevation 8010-8060. The available flow rate and/or quality of the water at either potential water source is unknown. At either source power will be required for pumping. Pumping stations and supply line costs are estimated at \$175,000 to \$180,000 per mile and assume three phase power is available.

From a facility design standpoint three-phase power is desirable to minimize initial capital cost and operating costs. The current best estimates for providing utilities and access to the site are given in Tables X.1, X.2, and X.3.

TABLE X.1. Unpaved Roadway Costs

Description	Length (miles)	Unit Cost	Total Cost
New roadway	4	\$500,000	\$2,000,000
La Ventana improvements	3	150,000	450,000

For purposes of our site facilities estimate, we have assumed the access road is capable of handling a 30-ft wide load, three-phase power is available at the site, and water is available at 20 gpm with a 15 psi residual pressure. It is assumed that the supply water will require minimal treatment.

X.2. BUILDINGS & SYSTEMS

The shops, garage, and pump house can be combined into a single building. All others stand alone. It may be desirable during final design to consider combining the offices and control buildings into a single structure. Square footages given are net usable floor space.

TABLE X.2. Power (3 phase) Costs

Description	Length (miles)	Unit Cost	Total Cost
I-40 to end of current road	10	$40,000	$280,000
I-40 to end of current road	3	40,000	120,000
(pole and wire mods only)	7	10,000	70,000
New Roadway	4	45,000	180,000
To Mesa Negra Spring	2	45,000	90,000

TABLE X.3. Water & Pump Station Costs

Description	Length (miles)	Unit Cost	Total Cost
From La Ventana (1410' rise)	7	$180,000	$1,260,000
From Mesa Negra (360' rise)	2	175,000	350,000

X.2.1. General Site - Facility Layout - Foundations

Figures X.1, X.2, and X.3 show the general site layout and include all site operational facilities and required infrastructure as described below. The site is assumed to be nominally 48 acres (1600×1300 ft) to accommodate the Array and related facilities. The site is covered with a ground cover of grass, small brush, and a moderate to dense growth of small pinion and juniper trees. The initial 6 in to 12 in of depth consists of cobbles, gravel, and root-laden clayey soils. Rock outcroppings exist. Below this surface layer is weathered and fractured bedrock suitable for structure foundations. Frost depth which is nominally $2 - 3$ ft in this area will control the depth of building perimeter foundations and utilities. Isolated interior slabs can be founded on the weathered and fractured near-surface bedrock. Depending on the telescope configuration, operational wind loadings on the telescopes and mounts, and assigned foundation pointing errors, the near surface weathered bedrock is likely suitable for the telescope foundations. The top rock layer, to nominally $12 - 14$ ft, is rippable with conventional equipment. It is reasonable to selectively grub and clear the site and preserve the natural site cover.

X.2.2. Operational Buildings

Eleven operational buildings and ten telescope sites were defined in the initial layout as being required for the array operation. We believe that functionally a number of the facilities can be combined to reduce construction, site utility, and access costs, and have developed the layout to reflect those economies. Operationally the site buildings are divided into three categories:

1. Optical collection and processing
    - OPLE (Optical Path Length Equalizer)

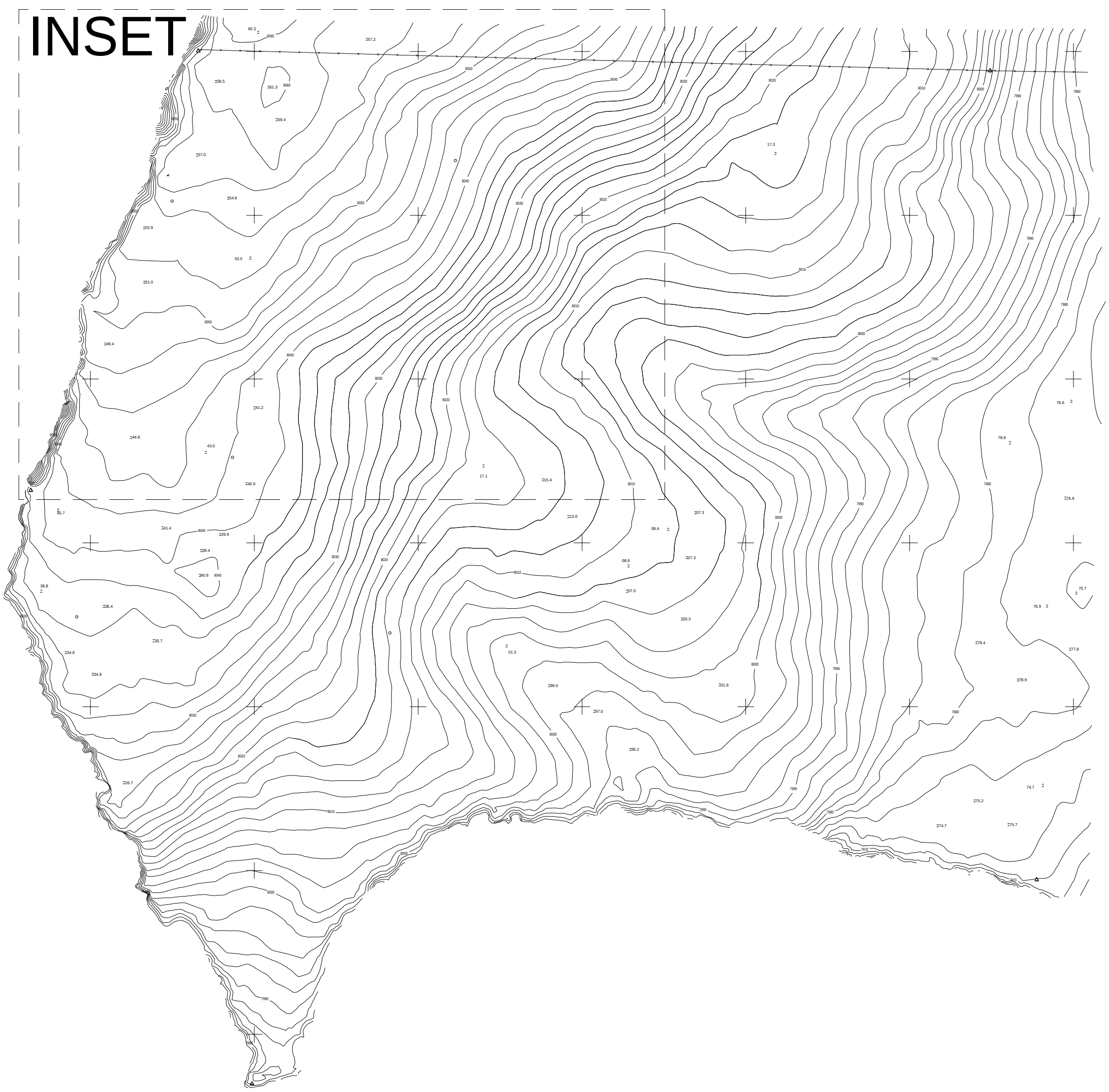

FIGURE X.1. Shown here is the topography of the site. Contours are 2′. The INSET is the location of Figure X.2.

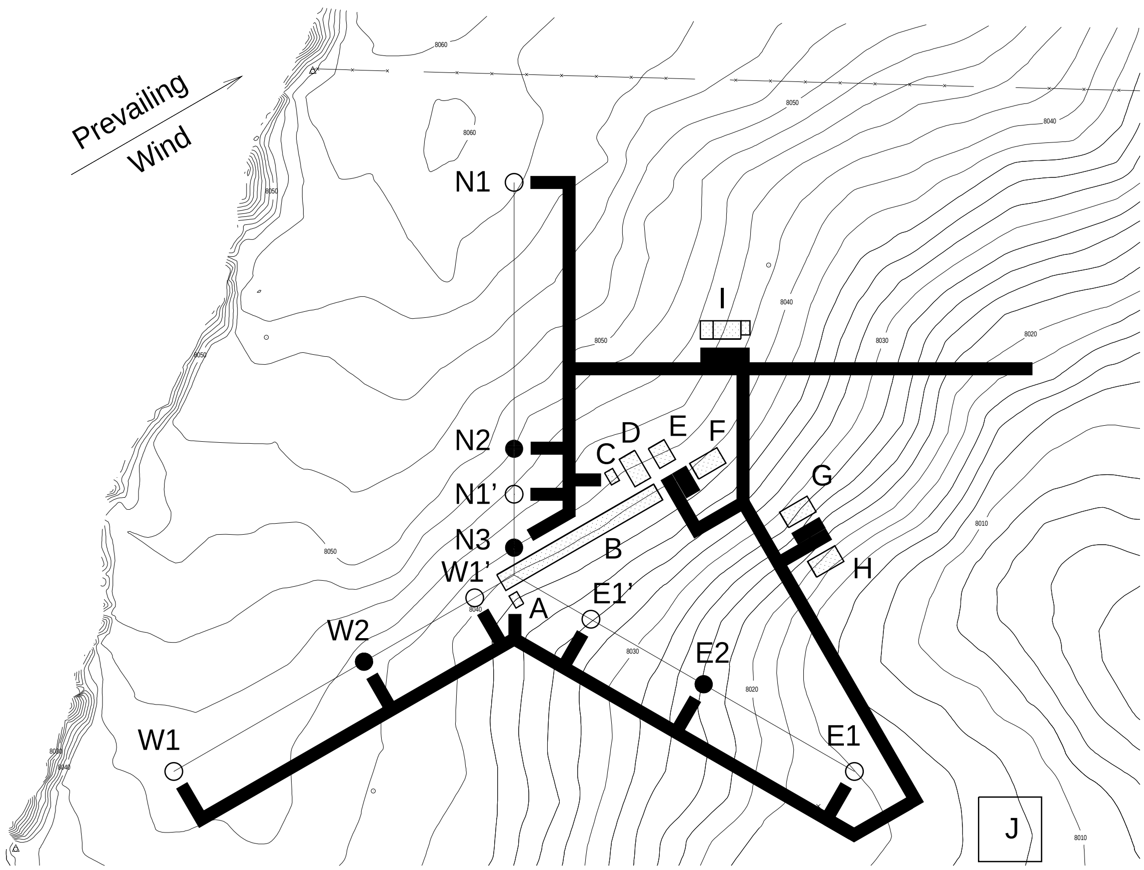

FIGURE X.2. Shown here is a zoom view of the site topography, as well as the Array configuration superimposed. Contours are 2′. Buildings, as shown in Figure X.3, are as follows: mechanical sheds (A+C); OPLE (B); BCL (D+E); offices (F); kitchen/lounge (G); sleeping quarters (H); and shops, garage, & pump house (I). Area J is the septic tank drain field. Locations N1, N2, N1′, N3, E1, E2, E1′, W1, E2, & W1′ are telescope locations.

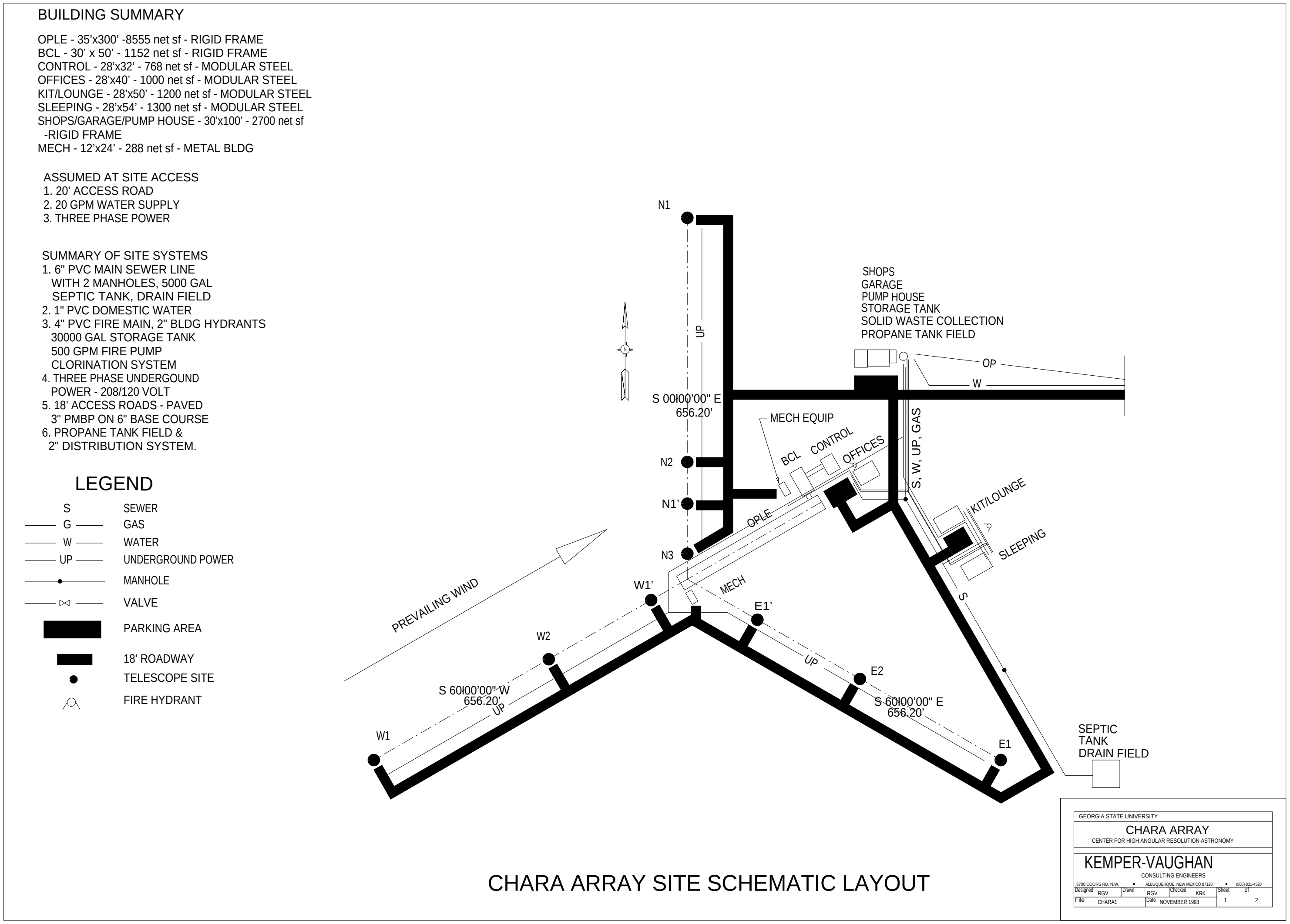

FIGURE X.3. Shown here is the CHARA Array schematic layout.

- BCL (Beam Combining Laboratory)
- Mechanical buildings
- Control buildings
- Office buildings

2. Site maintenance operations
   - Shops
   - Garage
   - Pump House building
3. Site living operations
   - Kitchen/Meeting/Lounge
   - Sleeping Quarters

Design requirements for each of these buildings is described in detail later. The site plan separates these operations functionally with due concern for access, utility service, light contamination, and noise.

X.2.3. Telescope

The Y-shaped telescope Array includes three 656 ft long legs oriented north, southeast, and southwest. The ten telescope locations require road access and power to each location as well as vacuum light pipes from each telescope to the OPLE building at the center of the array. The light pipes and their supports as well as the telescopes and their housings and foundations are excluded from this report.

X.2.4. Access Road & Parking

Access roads are required to be hard surfaced and dust free. A nominal 18 ft wide road surface will allow two vehicles to pass and is wide enough to accommodate the anticipated telescope and its transporter vehicle. It has been estimated that the telescope is expected to weigh nominally 6000 lbs. A road surface of 2 1/2 – 3 in of bitiminous paving and 6 in of crushed base course is sufficient for anticipated loadings and will eliminate dust. Parking for four to five vehicles is suggested at the building sites. Access roadways cannot cross the arms of the Y because of the light pipe configuration, hence access to the southwest and southeast arms extension is around the southeast leg. The north extension is accessed north of the control complex. General access to the site is from the east.

X.2.5. Water System

Supply water is assumed to be delivered to the site pump house area at 20 gpm with 15 psi residual pressure. This is sufficient to fill the storage tank in about 24 hours. The water system includes a pump house, 30,000 gallon steel storage tank, pressure booster pumps for domestic and fire flows, chlorination treatment, and associated piping. A 30,000 gallon storage tank will supply enough water to fight an on-site fire for approximately 1 – 2 hours without depleting the storage and is deemed adequate. The distribution system pipe size is controlled by fire flow requirements and length of non-looped runs and is estimated as 4 in PVC. Sprinkler systems are recommended for the OPLE and BCL buildings for the protection of equipment. Other buildings can be protected by conventional 2 in building hydrants. Domestic flows are nominally small. Fire flows at hydrants are recommended at 500 GPM at 60 psi. Isolation valves are provided as needed to avoid shutdown of the facility in the event of line breaks or outages. Minimum depth of bury for the waterlines is 3 ft.

X.2.6. Sewer System

The sewer system consists of 6 in PVC main lines, a 5,000 gallon packaged septic tank and drain field. The septic tank and drain field are located south of the sleeping quarters. Adequate slope exists to use gravity flow. Two manholes are required. Waste flows are minimal and no known contaminates are to be discharged to the system.

X.2.7. Propane Gas System

Natural gas is not provided at the site, however an on-site propane tank field and gas distribution system is recommended to provide fuel for the heating systems of the buildings, the emergency generator, and certain critical backup systems. Cost of the system is amortized very quickly in utility operational costs when compared to providing all electric heating and cooling units for the larger buildings. It is a very common system in remote areas and provides fuel to maintain the site in the event of power outages. Combined with a small emergency generator it will eliminate any requirement for a UPS system to stow telescopes. It is recommended to provide a fuel supply for one month operation. The distribution system is laid out to serve all building complexes. In the event natural gas is ever provided to the site, the system can be easily modified without change of any major equipment. A 2 in supply line is anticipated.

X.2.8. Power System

Three-phase power is assumed delivered to the site and then overhead to the Shops / Garage / Pump House Building. The main switchboard, transformer, emergency generator for telescopes and critical power, and principal electrical equipment are located at this building. 120/208 volt three-phase service is estimated for the OPLE building complex, shops building, and each telescope site. 120/208 single phase is estimated for the sleeping complex. Site power distribution is assumed to be underground in cable ductbanks from the main switchboard in the shops building to the respective facilities. Two banks are identified for the telescopes and OPLE complex, and sleeping complex. Site power, particularly telescope and optical equipment demand is unknown. Total site demand is estimated at 240 kva which assumes 5 kva for each operational telescope, 80 kva for OPLE and BCL, 50 kva for shops and pump house, 20 kva for all other buildings and an allowance of 25% for site growth.

X.2.9. Landfill - Solid Waste Disposal System

Private collection is the most economical method with an on-site central disposal collection site. The shops area is the logical site and provisions should be made to handle either bulk bagged or compacted solid waste as well as drum collected liquid wastes, i.e. oils and other chemicals if anticipated, and metal wastes. An allowance is provided in the cost estimate for site development and containment equipment.

X.3. BUILDINGS

Buildings can be site constructed or in some instances for ecomomy built off site and delivered to the site for finishing. The site is very remote. Labor and transportation costs will be about 20% higher than typical construction off the mesa top. As such it is desireable to minimize site constructed items where possible. Building configurations and materials have been suggested to reduce the on-site work. Excavation costs are high because of the near surface rock and sites should be developed at existing grades where possible. Disposal of construction waste and operational solid waste is also very costly and design should minimize these costs. Single-line plans of the various building are shown as Figure X.4.

X.3.1. OPLE Building

This building is nominally $35 \times 300 \times 14$ ft eave height and will be a typical rigid frame pre-engineered structual steel building with steel panel roof and siding for the outer shell. The shell structure requires weather tightness and insulation beyond normal industrial buildings. To accomplish this it is proposed to use batt insulation, nominally R-36, in the walls and roof with interior steel/gypboard wall and ceiling cover for enhanced weather tightness and temperature control. Foundations are economical turned down slabs. Two equipment doors are assumed at the ends.

The interior isolated slab for the light path equipment, nominally 21×280 ft, can be 6 in thick and founded on the near surface rock. The interior structure can utilize steel studs/gypboard walls and ceiling. Clear height is assumed at 9 ft. Two equipment doors are assumed at the ends.

Lightning protection and ground counterpoise are provided. Outer and interior shell lighting are assumed surface mounted. Smoke detectors and alarms are assumed for both the interior and outer shells. Sprinklers are assumed for the interior shelter for equipment protection.

Power demand for the OPLE is estimated at approximately 65 kva.

Unknown at this time is the demand generated by equipment used to move the optical equipment. Similarily HVAC (High Volume Air Conditioning) control, particulary heat loads developed by optical equipment in the inner shelter is unknown. As a result, specific HVAC equipment cannot be completely identified. It is also desirable to limit vibration from HVAC equipment which suggests isolation of the equipment outside the building and limited air duct velocities within the interior spaces. It is safe to assume at the elevation of the facility that heating is likely to control equipment sizes. The HVAC system is recommended as a multizone system with zones for the outer shelter and inner shelter using gas-fired exterior slab mounted units and electrical cooling. Since air flow in the inner shelter is not desired during observing operations, controls for the zone operations can be provided which limit air flows in the inner shelter. The building volumes are approximately 56,000 ft^3 for the inner shelter and 91,000 ft^3 for the outer shelter. It is desirable to maintain a near constant temperature ($\pm 2^\circ$ over a 1 hour period) in the inner shelter during observation with no air flow. As we understand, the optical equipment will likely be moved with small stepper motors. Depending on sizes, heat load could be generated into the inner shelter. It is conceivable that a three-zone system would emerge with the third zone cooling only the light table transportation system. This is a difficult design problem, and during detailed design these items need to be carefully coordinated with the HVAC design to achieve the desired results. For purposes of estimating power and HVAC-related costs the power budget is estimated in Table X.4.

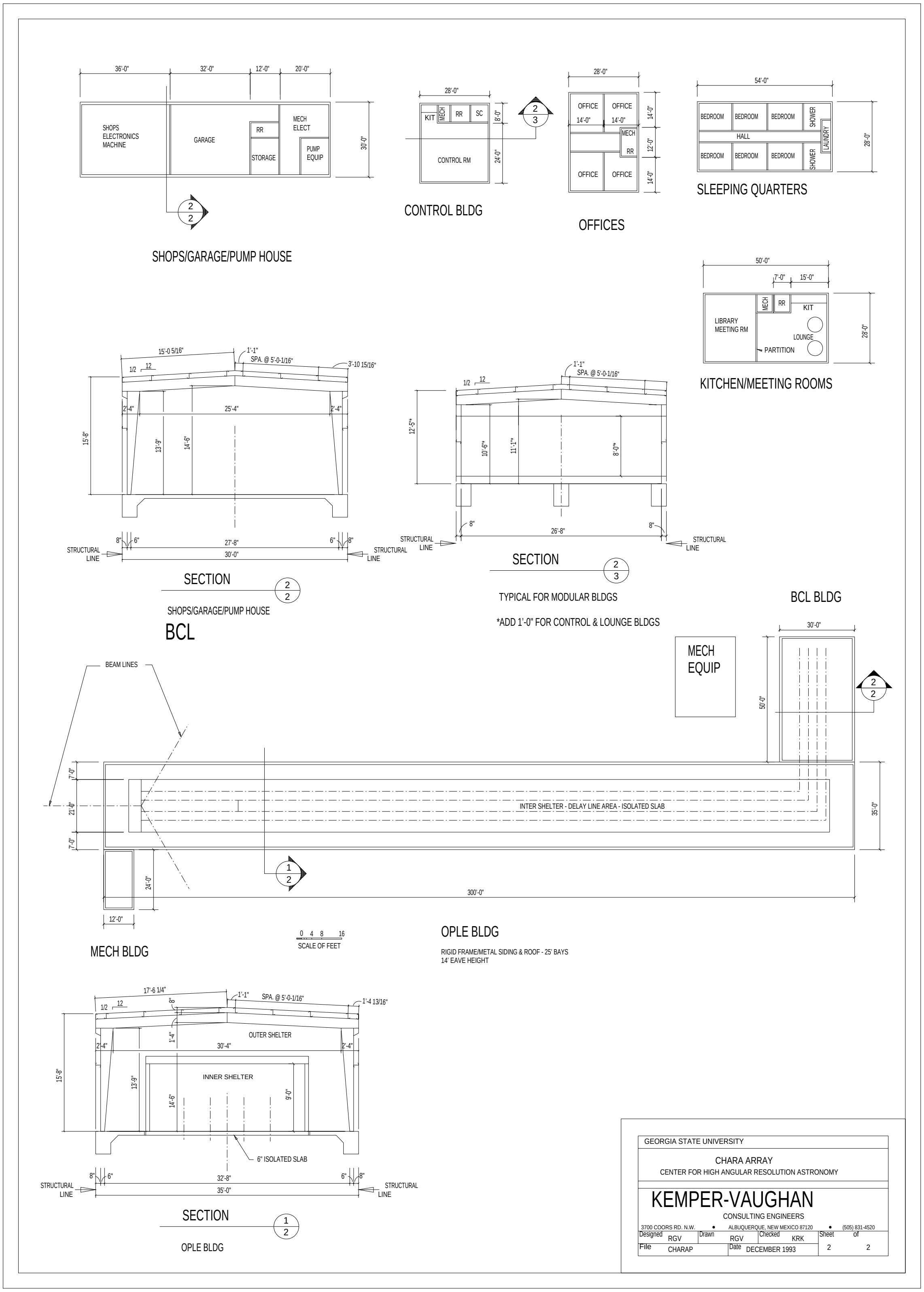

FIGURE X.4. Shown here are the building plans.

TABLE X.4. OPLE Building Power Requirements

Item	Power Requirement (kva)
Lighting	20
Miscellaneous Power	10
HVAC	25
Optical Equipment	10

X.3.2. BCL Building

This building is nominally 30×50×14 ft eave height and will be a typical rigid frame pre-engineered structural steel building with steel panel roof and siding for the outer shell. The shell structure requires weather tightness and insulation beyond normal industrial buildings. As with the OPLE building, it is proposed to use batt insulation, nominally R-36, in the walls and roof with interior steel/gypboard wall and ceiling cover for enhanced weather tightness and temperature control. Foundations are economical turned down slabs. The building is assumed attached to the OPLE with equipment doors.

The interior slab for the optical tables is not isolated. Optical equipment to be provided contains its own isolation system.

Lightning protection and ground counterpoise are provided. Lighting is assumed surface mounted. Smoke detectors, alarms and sprinklers are assumed for the building.

Power demand for the BCL is estimated at approximately 15 kva.

Unknown at this time is the demand generated by electronics equipment and the optical equipment. Similarly HVAC control, particulary heat loads developed by moving optical tables in the building, is unknown. As with the OPLE building, the HVAC equipment cannot be completely identified. It is also desirable to limit vibration from HVAC equipment. The HVAC system is recommended as a single zone system using a gas-fired exterior slab mounted unit. It is desirable to maintain a near constant temperature (±2-degrees over a 1-hour period) in the building during observation. If the optical tables require movement, heat loads may be developed. During detailed design, these items need to be carefully coordinated with the HVAC design to achieve the desired results. For purposes of estimating power and HVAC related costs the power budget is estimated in Table X.5.

TABLE X.5. BCL Building Power Requirements

Item	Power Requirement (kva)
Lighting	2
Miscellaneous Power	5
HVAC	5
Optical Equipment	3

X.3.3. Mechanical Storage Building

This building houses the vacuum pump system for the beam tube system. It is assumed at 12×24 ft and could be either a small pre-engineered steel structure or steel modular construction delivered to the site. It requires no cooling, minimal power, heating, and lighting. No water or sewer service is anticipated. Power for the building is from the telescope service line. Lightning protection is incorporated into the OPLE building. A 6 ft double-service door is included.

X.3.4. Control Building

This building houses the control room, small storage room, restroom, and small kitchen unit. It is nominally 50×28 ft and steel modular construction delivered to the site. Ceiling height is 9 ft. Heating can be provided by a small gas-fired unit built integrally with the building and ceiling ducts. A conventional commercial kitchen, i.e. sink, range unit, and refrigerator, is assumed. On-site foundations, plumbing, and electrical rough-in are required. Lightning protection is provided. Cable trench to the BCL is estimated. Cable ducts can be preset in the building floor. Smoke detectors and alarms are assumed for the building.

X.3.5. Office Building

This building houses four offices and a restroom. It is nominally 50×28 ft and steel modular construction delivered to the site. Ceiling height is 8 ft. Heating can be provided by a small gas-fired unit built integrally with the building and ceiling ducts. On-site foundations, plumbing, and electrical rough-in are required. Lightning protection is provided. Smoke detectors and alarms are assumed for the building.

X.3.6. Garage/Shops/Pump House Building

This building is nominally 30×100×14 ft eave height and a typical rigid frame pre-engineered structural steel building with steel panel roof and siding for the outer shell. Foundations are economical turned down slabs. The building houses the shops, garage, vacuum pump house, site electrical transformer, emergency generator, related equipment, and storage space.

Lightning protection and ground counterpoise are provided. Lighting is assumed surface mounted. Smoke detectors and alarms are assumed for the building.

Power demand for the shops is estimated at approximately 50 kva, principally for the pumps and emergency generator eupiment.

X.3.7. Kitchen/Lounge/Meeting Building

This building houses the kitchen/dining area, small storage room, restroom, kitchen unit, and general meeting room/library. It is nominally 50×28 ft and steel modular construction delivered to the site. Ceiling height is 9 ft. Heating is provided by a small gas-fired unit built integrally with the building and ceiling ducts. A conventional commercial kitchen unit is assumed. On-site foundations, plumbing, and electrical rough-in are required. Lightning protection is provided. A moveable curtain partition with access door is assumed to partition the dining/meeting areas. Smoke detectors and alarms are assumed for the building.

X.3.8. Sleeping Quarters

This building houses six individual bedrooms, two restroom shower areas, and laundry units. It is nominally 54×28 ft and steel modular construction delivered to the site. Ceiling height is 8 ft. Heating is provided by a small gas-fired unit and ducts built integrally with the building. Conventional laundry washers and dryers are provided. On-site foundations, plumbing, and electrical rough-in are required. Lightning protection is provided. Smoke detectors and alarms are assumed for the building. Interior partitions, exterior walls, and doors should be constructed with sound isolation materials.

X.4. CONSTRUCTION COST ESTIMATE

X.4.1. Estimated Construction Costs

Total estimated construction costs are summarized in Table X.6 by building designation and general site work. A detailed cost summary has been provided to CHARA. Costs have been broken out by various building systems or site systems on a square foot, lineal foot, or other unit of measure. They represent current unit costs, modified as necessary, to reflect local site conditions and location. As presented the various units are summarized as bare construction costs with general contractor markups provided for the entire construction. The total markup can be applied to each building or the site work to provide individual costs. This markup is 35.35% exclusive of contingency. A contingency of 30% has been added to account for the preliminary nature of the estimate and unknown construction time frame.

TABLE X.6. Estimated Construction Costs

Item	Bare Cost		With Markup		With Contingency
	cost/sf	total cost	cost/sf	total cost	
OPLE	$76	$ 802,695	$103	$1,086,448	$1,412,382
BCL	76	106,553	96	144,219	187,485
Shops	76	107,115	48	144,980	188,474
Control/other	76	293,846	81	397,721	517,037
Site		414,680		561,269	729,650
Totals		$1,724,890		$2,334,763	$3,035,192

X.4.2. Engineering Costs

Engineering design costs are nominally 6% of estimated construction cost plus field and suplemental costs. These are summarized as follows and are based upon the construction costs with contingency.

X.4.3. Bidding Considerations

Labor rates for in state and government projects are separated into two classes: Class B for highway, utility, and site, and Class A for building trades. Class A rates are higher and

TABLE X.7. Engineering Costs

Item	Cost
Design	$182,111
Site Survey	39,106
Soils Testing/Percolation	39,106
Construction oversight	391,056

apply to on entire project if that project contains any building trade activity. This means that the Site Access work classifies as B work. Some economies for the entire project can result if the CHARA site work and Site Access work could be bid as a single package or possibly two phased projects, with the building components bid separately. Telescope site development and light pipe work would similarly qualify as Class B work.